SALMON RECOVERY SCIENCE REVIEW PANEL
Report for the meeting held
December 11-13, 2002
Northwest Fisheries Science Center
National Marine Fisheries Service
Seattle, WA

This introductory material (pp. i-iii) is available on the RSRP web site, but as an aide to the reader we are now including it with individual reports.

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Recovery Science Review Panel

The Recovery Science Review Panel (RSRP) was convened by the NOAA Fisheries to help guide the scientific and technical aspects of recovery planning for listed salmon and steelhead species throughout the West Coast. The panel consists of six highly qualified and independent scientists who perform the following functions:

1. Review core principles and elements of the recovery planning process being developed by the NOAA Fisheries.

2. Ensure that well accepted and consistent ecological and evolutionary principles form the basis for all recovery efforts.

3. Review processes and products of all Technical Recovery Teams for scientific credibility and to ensure consistent application of core principles across ESUs and recovery domains.

4. Oversee peer review for all recovery plans and appropriate substantial intermediate products.

The panel meets 3-4 times annually, submitting a written review of issues and documents discussed following each meeting.

Expertise of Panel Members

Panel members have all been involved in local, national and international activities. They have served on numerous National Research Council committees and have published many papers in prestigious scientific journals.

Dr. Robert Paine (chair), University of Washington

- *Field of expertise*: marine community ecology, complex ecological interactions, natural history
- *Awards*: National Academy of Sciences member; Robert H. MacArthur award recipient from the Ecological Society of America; Tansley Award from the British Ecological Society; Sewall Wright Award from the American Society of Naturalists; Eminent Ecologist Award from the Ecological Society of America
- *Scientific leadership*: Member of multiple National Research Council committees, editorial boards, past president of Ecological Society of America
- *Research*: About 100 scientific publications

Dr. Ted Case, University of California-San Diego

- *Field of expertise*: evolutionary ecology, biogeography and conservation biology
- *Awards*: Board member for National Center for Ecological Analysis and Synthesis; Guggenheim Fellow, American Academy Of Arts And Sciences; Research featured in prominent scientific journals (Science, Nature) popular science journals (American Scientist, Discover), on public television and public radio
- *Scientific leadership*: Chair of Department of Biology at UCSD and author of leading textbook on theoretical ecology;
- *Research*: More than 116 scientific articles published

Dr. Frances C. James, Florida State University

- *Field of expertise*: conservation biology, population ecology, systematics, ornithology
- *Awards*: Eminent Ecologist Award from the Ecological Society of America; Leadership and dedicated service awards from the American Institute of Biological Sciences
- *Scientific leadership*: Participant on National Research Council Panels; service on many editorial boards; Board of Governors for The Nature Conservancy; scientific advisor for national, state and local activities
- *Research*: More than 105 scientific articles published

Dr. Russell Lande, University of California-San Diego

- *Field of expertise*: evolution and population genetics, management and preservation of endangered species, conservation and theoretical ecology
- *Awards*: Sewall Wright Award from the American Society of Naturalists; Guggenheim Foundation, MacArthur Foundation, American Academy of Arts and Sciences; Fellow of the American Academy of Arts and Sciences
- *Scientific Leadership*: President of the Society for the Study of Evolution; International recognition; developed scientific criteria for classifying endangered species adopted by the International Union for Conservation of Nature and Natural Resources (IUCN)
- *Research*: More than 116 scientific publications

Dr. Simon Levin, Princeton University

- *Field of expertise*: theoretical and mathematical ecology, evolutionary ecology,
- comples ecological systems
- *Awards*: National Academy of Sciences member; Robert H. MacArthur award recipient from the Ecological Society of America; Statistical Ecologist Award from the International

Association for Ecology; Distinguished Service Award from the Ecological Society of America; Guggenheim Fellow, American Academy Of Arts And Sciences; Okubo Prize, society for Mathematical Biology and Japanese Society For Theoretical Biology
- *Scientific leadership*: Member of many National Research Council committees; Board of Directors member for Santa Fe Institute, Beijer International Institute of Ecological Economics, the Committee of Concerned Scientists; Past President, Ecological Society of America past president, Society for Mathematical Biology
- *Research*: More than 300 technical publications

Dr. William Murdoch, University of California Santa Barbara

- *Field of expertise*: theoretical and experimental ecologist, population ecology
- *Awards*: Robert H. MacArthur award recipient from the Ecological Society of America; President's Award from the American Society of Naturalists; Guggenheim Fellowship
- *Scientific leadership*: Founder of National Center for Ecological Analysis and Synthesis; Director of Coastal California Commission 10-year study; scientific advisory panel member for the Habitat Conservation Plan for the California marbled murrelet
- *Research*: More than 125 scientific publications

Dr. Beth Sanderson

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- Recovery Science Review Panel report coordinator

RECOVERY SCIENCE REVIEW PANEL (RSRP)
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I. AN EVALUATION OF NOAA FISHERIES RESPONSE TO RSRP RECOMMENDATIONS

The RSRP sought and received an analysis of whether Pacific Northwest NOAA Fisheries was responding both to committee recommendations for "new" science [e.g., testing the efficacy of barging smolts in the Columbia or employing hatcheries as experimental units], and our concerns with models and model assumptions [e.g., EDT] or incorporation of realistic assessment of the role that stochastic influences could play in ESU recovery. Committee members sought assurances that their commitment of time and energy wasn't simply falling into a black hole. If so, the committee could be defined as simply another advisory group. Under that verdict, the panel probably would have disbanded.

The time-consuming and generally effective Pacific Northwest NOAA Fisheries response was presented as a series of seven white papers. These were discussed in a closed meeting with both Usha Varanasi and Bob Lohn since many of the committee's suggestions necessarily involve the cooperation of other federal, state and tribal authorities. Their implementation obviously involves communication between and cooperation of a variety of agencies. This may well be "mission impossible" unless the issue can be argued to be of fundamental importance to salmon ESU retention. One model might be the Clinton administration's "Forest Summit." Some issues would require coordination of the Departments of Commerce and Interior. The current financial atmosphere doesn't fill one with optimism, especially if environmental issues are expected to be addressed at local scales. On the other hand, the NWFSC has responded positively to RSRP suggestions in a number of areas, and the more global concerns about use of hatcheries and salmon habitat preservation and restoration appear to be highly ranked on the regional NOAA Fisheries' agenda. The resulting discussion introduced the subject of whether, or how, the RSRP might become a more effective advocate for global perspectives and actions relating to salmon ESU restoration.

A. Ecosystem Diagnosis and Treatment

The structure of EDT does not have sufficient empirical basis, and model predictions are unlikely to be reliable or robust. Most of the unwieldy set of parameters cannot be estimated with any degree of confidence, and this simply exacerbates the problem of prediction. Models like EDT give a false sense of precision. The RSRP believes that simpler and more reliable models are needed.

B. Habitat Delisting Criteria and Habitat Improvement

The work described by NOAA Fisheries in this area is completely consistent with the recommendations of the RSRP. Panel members would like to see the scale of the experiments ratcheted up and the design of the experiments planned to have replication and control.

C. Barging

Panel members appreciate that for numerous reasons testing the "deferred mortality" hypothesis is nearly intractable. This is a sad situation because the question is so important. Implementation of the proposal to NWPPC would be fine. It would have to be repeated for perhaps three years so that differences among treatments could be seen without idiosyncratic year effects. The RSRP would certainly like to meet more NOAA Fisheries scientists to learn more about what is going on in the agency.

D. Beyond the 4Hs

NOAA Fisheries has interesting ongoing projects in this area. The committee's recommendations included putting priority on interspecific actions that might be having large effects and that might be subject to management. Of course the research itself will involve manipulations. Panel members think it should be designed to allow comparisons about the relative strengths of interactions, if at all possible. Of course, having science writers is a good idea, especially because a large fraction of the public has only a dim understanding of what goes on in research and is generally unfavorable toward government activities.

E. Integration

NOAA Fisheries agrees with our recommendation and is pushing for better integration in monitoring and between the TRTs. Although still in its initial stages, 4H analysis is a good example of an attempt to construct a large database that covers many individual cases (tributaries) and their attributes. It seems that integration among local stakeholders will be a future theme. We are actually more concerned about integration among agencies and regions. The 4H database may provide the information needed for setting up comparisons that lead to some inferences about causes of declines in salmon. It may also provide the information needed for selecting sites for experimental treatments and controls.

F. Hatcheries

If hatchery funding has not been keeping pace with hatchery costs, then the committee thinks some should be closed and the choices should be made so that future comparisons will allow inferences about the impact of hatchery on wild fish. Estimates of costs and power tests of the sample sizes needed to detect specified levels of responses will have to be conducted first. Panel members think that this is such an important question that it should have the highest priority. This point is further emphasized by the Independent Scientific Advisory Board in its report "Hatchery Surpluses in the Pacific Northwest." The ongoing fitness experiments seem to be excellent. We understand the serious data problem and can only say that standardized efficient monitoring schemes are urgently needed.

G. Harvest

Again, it will take planned comparisons to evaluate the impact of harvest. Panel members look forward to the paper now in development that explains the current system for setting harvest rates. There has certainly been a history of poor integration among the dynamics of the production of salmon in hatcheries, the setting of harvest levels, and the status of wild populations. The overall goal should be to get these three components into something resembling an acceptable steady state. Understanding this complex system is a tremendous challenge, but without such understanding, managers are really working in the dark. There are common sense policies that may or may not help. The RSRP's philosophy is that NOAA Fisheries should work toward figuring out which alternative management policies are most likely to help wild salmon. The only way to do that is to make sets of comparisons in which the effects of management options can be ordered. The clearest results will be from well-designed experiments but when that is not feasible other types of comparisons can lead to albeit weak inferences.

II. TOP DOWN AND BOTTOM UP MANAGEMENT—LOCAL DECISION MAKING IN A REGIONAL FRAMEWORK

A. THE PROBLEM DEFINED

The challenge of salmon management in the Northwest is a classic problem in the management of complex adaptive systems. On the one hand, restoration must take a broad system-wide perspective because linkages among multiple populations and environments, occurring over large spatial scales, crucially govern salmon dynamics. On the other hand, local socio-economic factors inevitably exert strong influence on management decisions. Both spatial scales are important; so we must find systematic ways to integrate them.

Having stakeholders make local decisions is a good idea, but only if it is within a larger framework planned to allow future comparisons. It is those planned comparisons that will be the basis of inferences about the relative importance of various causes of declines, and about the relative efficacy of different approaches to recovery. Now is the time to set up a preliminary framework. These issues have seen sophisticated development in the management literature in recent years, as in the work of Carpenter at Wisconsin, or Ostrom and Moran at Indiana, but the hodge-podge approach currently in practice for salmon shows no cognizance of recent advances. No doubt this failure reflects to some extent the fragmented nature of the jurisdictions governing salmon management. Nevertheless, it is not even evident that anyone is thinking about the problem at the level of the whole system or at appropriate regional scales. As an alternative to a grab-bag collection of idiosyncratic local initiatives, the committee strongly believes, and has insisted in the past, that a comprehensive master plan is needed to provide a framework for rational decision making at the local level.

There are many dimensions to this problem, all of which have been raised before.

(1) It is insufficient to consider individual factors, such as the 4Hs, in isolation. Heightened attention must be given to the interplay among factors, and to an integrated approach to management. The TRTs have begun to do this, but the dominance of the individual factors continues to have too much influence.

(2) It is scientifically essential to have a common set of criteria, for example, relating to population status, that can be applied across the various TRTs. That is not to deny that individual systems will differ in the importance of different factors; but these differences must be evaluated within a common framework.

(3) Perhaps most importantly, a common set of management criteria are needed. Developed at the national level, these criteria would be the foundation upon which rational local decisions can be made. It is unwise to cede such decisions to local decision makers. Not only will vested interests then assume undue importance, the incoherence of actions across systems will lead to strategies at cross-purposes with one another. As discussed further below, a synthetic framework that goes beyond isolated decision making could be developed. That framework would then allow learning-through-action, and make successful recovery much more likely.

(4) Crucial in the integrated, cross-system approach is the design of recovery actions as experiments that can test the importance of particular factors. These experiments, in the committee's view, are the only way to answer the central questions about the importance of different factors in different systems, and obviously must involve cooperation and integrated

planning across local systems. It has become clear to us that there is some resistance within the TRTs to carrying out experiments, perhaps because these are perceived as issues that must be resolved above the level of individual TRTs, and perhaps because they are opposed by local economic forces beyond the control of scientists. It is thus essential for regional and national leadership to find ways to implement this key recommendation, which has been reinforced by virtually every oversight committee that has examined the problem. Ultimately, this imperative may need to be carried to appropriate offices in Washington to create the incentives and support.

B. PRINCIPLES UNDERLYING SUCCESSFUL RECOVERY ACTIONS

The committee recognizes that many recovery actions will be taken by local jurisdictions. Two factors will make recovery difficult to achieve if there is only local decision-making.

(1) Although many important processes occur at the spatial scale of local jurisdictions, many occur at much larger scales, and all processes integrate and interact to determine salmon productivity over larger spatial scales. The effect of local actions on salmon recovery therefore cannot be estimated only locally.

(2) All of these processes occur in temporally and spatially variable environments. The effect of single actions, therefore, cannot be determined outside of a framework that accounts for spatial and temporal variability.

The challenge is how to optimize the process of recovery, given these conditions. The committee believes that the following are prerequisites for success.

1. Recovery actions must be viewed in a specific overall framework of Active Adaptive Management (AAM). Decisions will always be made in an uncertain world; AAM results in comparisons that allow inferences about the causes of differences. Then future management is adjusted to accommodate the new knowledge.

2. AAM requires an explicit experimental framework in which each local decision is a component of a spatially larger design. This requires that each local jurisdiction make decisions in coordination with other jurisdictions in the region.

3. AAM requires that measurements of the effects of actions in different areas are in common units estimated by the same protocols so they can be evaluated in a common framework.

4. Because different processes affecting salmon integrate over large regions, i.e. across the salmon life cycle (point (1) above), there needs to be a common scientifically sound framework for exploring the likely effects of different recovery actions on overall salmon ESU productivity.

5. Points 3 and 4 establish that local decision-making needs to take place in an explicit national/regional scientific framework. It should be the job of regional administrators and scientists to work together to create the overall framework.

C. SCENARIOS TO ILLUSTRATE THE NEED TO EMBED LOCAL DECISIONS IN A SPATIALLY LARGER SCIENTIFIC FRAMEWORK

The following scenarios illustrate a few of the problems inherent in isolated local decision-making. In particular, they show the need to integrate actions and observations across similar units (such as streams) in the region, and across different types of units (e.g. streams and estuaries) in the region.

The scenario supposes that the local jurisdiction covers all or part of a watershed that is itself one of several that contribute juveniles to a single salmon stock, that all of the juveniles pass through the same estuary en route to the ocean, and that there is temporal variation in all parts of the environment, which may or may not be correlated among the different parts (streams, estuary, ocean).

Scenario A. An upstream jurisdiction improves littoral vegetation along the main stream in the watershed.

<u>Interpretation at the local level</u>. The following three outcomes are possible. They illustrate the need to treat a single stream improvement as only one unit in a replicated experiment.

A1. An increase in juvenile densities is detected over several years in the improved stream. The local jurisdiction will conclude that improving stream conditions contributes to salmon recovery. However, in reality, changes in regional forests improved stream conditions in the general area – juvenile density increased at the same rate in unimproved streams, but these "controls" were in a different jurisdiction and were not measured.

A2. No change in juvenile density was detected over several years, and the local jurisdiction concluded the recovery action had no effect. However, in reality, changes in forest conditions degraded streams in the area over this period, and juvenile density in fact decreased in unobserved unaltered streams in nearby jurisdictions. The improvement prevented this decline in the action stream, but this fact was not detected.

A3. An increase in juvenile densities is detected over several years in the improved stream. The local jurisdiction will conclude that improving stream conditions contributes to salmon recovery. In this case they are correct – the general conditions of streams in the area stayed about the same, as did juvenile density in unimproved (and unobserved) streams. Unfortunately, no causal inferences are possible because there were neither replicated nor control streams. Positive or negative results might well be due to variables other than those that were manipulated.

Extended scenario A. Imagine, now, that unknown to those managing the stock, the estuary is a bottleneck to salmon production; i.e., production from local watersheds is usually much in excess of estuarine capacity. Suppose, further, that we can measure productivity of the stock as a whole, perhaps through observations near the estuary.

<u>Interpretation of effects at the stock level</u>. In all 3 cases above (A1-A3), there will be no change seen in stock productivity. In the absence of understanding what limits the stock, the stock assessors will be unable to determine the effect of upstream actions on recovery.

This illustrates the need for integration across the environments affecting an ESU or stock. For example, a stock-wide dynamic framework (probably a model) could evaluate how production and survival at various life stages affect overall stock production (λ). It also illustrates the need for an experimental approach at different spatial scales, as described next.

The next scenario illustrates that the need for a replicated experimental design extends to larger units, such as estuaries, hatcheries, or sets of dams. We use estuaries to make the point.

Scenario B. *Assume that a recovery action is taken only at an estuary, and we do not know if estuarine conditions limit production*.

Three outcomes are possible that are analogous to those seen in the stream.

B1. Salmon productivity increases, but in reality this reflects improved general estuarine conditions caused by oceanic changes. It is wrongly concluded that the action increased fish production.

B2. Salmon production did not change significantly, but in fact estuarine conditions in general deteriorated because of deteriorating oceanic changes. It is wrongly concluded that the action did not improve salmon productivity.

B3. Salmon production increased and, in fact, estuarine conditions in general stayed constant. It is correctly concluded that the action improves salmon production, but no causal inferences are possible because there were neither replicated nor control estuaries. Positive or negative results might well be due to variables other than those that were manipulated.
Cases B1-B3 illustrate the need for a replicated experimental design, with controls, at the spatial scale of estuaries.

In previous reports, the committee has made the same case for experimental manipulation of hatcheries. Committee members previously recommended replicated and controlled closures of hatcheries, because the same principle applies to alterations in management practices at hatcheries. Hatchery closure is the experiment with the greatest potential to elucidate both the positive and negative effects of hatchery production on the wild population.

D. Choosing Among Different Types Of Actions: The Need For Experiments Integrated Across Space

In reality, recovery actions will often be possible in streams, estuaries, surrounding lands, at harvest, at dams etc. Since resources are limited, and since different actions gore different political oxen, it will often be necessary to choose from among different possible actions. This is also an opportunity to use AAM to approach optimal solutions.

Thus, in the above scenarios, a more effective experimental design might be to carry out recovery actions at both streams and in estuaries, using the actions as different treatments in an experiment. Other experimental comparisons might be made between changes in harvest and changes in hatchery activity.

E. MAXIMIZING BANG FOR THE BUCK

The above scenarios focus on how to determine whether a particular action actually contributes to recovery. But, given limited resources, committee members would really like to measure the *amount* of recovery gained from a given recovery action – and hence for a given cost. For example, if both reduced harvest and altered hatchery management increase the rate of recovery (λ), then how much is gained from each forgone dollar of harvest and of hatchery production? While such questions will never be answered precisely in the real, noisy world, the answers may be precise enough to rank alternatives, or to determine how much action is likely to be enough.

The arguments for an explicitly experimental approach to determining whether an action has a positive effect, apply *a fortiori* when seeking to estimate the *size* of the effect of a given action. Replication of action and control is again essential. The better replicated and controlled the design, the more precise the estimates of the sizes of the effects. The RSRP recommends that NOAA Fisheries develop a preliminary framework based on principles of experimental design (randomization, replication, and control) and that the local decision-making process be given latitude to make decisions only within this framework. As the program develops, information from repeated comparisons will be useful in selecting among future management options and the framework itself can be modified and improved

III. COMMENTS TO TRTS - INTERACTING WITH TRTS

The RSRP met with a few representatives of all the TRTs collectively rather than, as in the past, most members of one or two of these groups. The intent was to generate an informal discussion of general or "universal" problems. The format seemed successful and should provide a template for future meetings, since one of the RSRP committee's roles is to provide technical advice. As noted elsewhere in this document, one of the panel's desires is to develop a strong argument and mechanism for some level of top-down influence. Meeting with all TRT leaders simultaneously appears to be an effective means of attaining this goal.

Discussions centered on challenges common to all TRTs.

1. How to deal with uncertainties implicit in defining population boundaries and classification?
2. Are "productivity criteria" useful given regionally varying sampling situations?
3. What is the appropriate level of life-history diversity, and how should the hierarchy of significance be determined?
4. How to account for uncertainty, both demographic and environmental, at the ESU level?
5. How to structure and incorporate expert opinion in data poor cases?
6. How many populations does an ESU need for viability (see #1)?
7. What will be the appropriate role of the TRTs in Phase II?

The RSRP has touched on all the above in previous reports. These reports provide a set of themes capable of uniting regional TRTs faced with different ESU circumstances and databases. For instance, themes #1 and #6 relate to the uncertainty associated with not knowing the historic or currently realized spatial distribution of an ESU. If the component populations were based on a too restricted spatial scale, their individually reduced population sizes will increase the chance of local extinction driven by stochastic influence. On the other hand, increasing a population's spatial domain will tend to average out variation, but also reduce the number of regional populations. Related issues are "costs": there will be financial cost associated with monitoring too many units; there will also be ecological costs associated with the "error" of including a population when unnecessary or excluding one when such a recognition is necessary.

Themes #2, #3, and #4 relate to challenges characteristic of salmonid biology. Theme #2 identifies the continuing dilemma of whether population numerical abundance or rate of change (lambda) should provide the primary input to regulatory decisions. How does one interpret and react to persistent declines in large populations (those numerically well above listing thresholds) vs. a listed ESU tending to increase? Buried in here is another major dilemma: current vs. historical measures of habitat "quality" and therefore "K" (carrying capacity). Life-history diversity (#3) involves issues of ESU spatial spread. Basic to these concerns are answers to the questions of how will the TRTs develop strategies for including a sufficient range of diversity metrics to meet viability criteria and equally, how many populations must there be in an ESU? (#6 also)?

Theme #5 was covered in the December 2000 meeting report. Expert opinion, like traditional knowledge, has substantial value. The challenge is how to use it, and whether and how it can be made more quantitative.

The panel believes it is premature to even guess what role TRT expertise will play in phase II (theme #7). Although all the TRTs are now formed, there are substantial differences in their progress towards formulating recovery strategies. If the RSRP's experience applies, TRT attainable goals, procedures, and the relative weightings of harvest, habitat and hatchery contributions will continue to evolve. Not only are there numerous environmental uncertainties (PDOs, ENSOs, climate change, etc), there are also developmental and political uncertainties. See Ruckelshaus et al. (2002) for discussion of some of these issues. More time is needed for the TRTs to mature before the vital issue posed in #7 can be addressed.

In summary, while this meeting presented no true opportunity for discussion of any issue or problem in depth, it represents a benchmark on a number of grounds. First, the informality of a roundtable format appeared to enhance discussion and avoid the acrimony occasionally associated with more formal presentations. And second, it suggests a means by which the RSRP committee can influence the more global and therefore generalizable attributes of salmonid recovery.

IV. HATCHERIES AS EXPERIMENTAL UNITS

The RSRP continues to be concerned with and intrigued by hatcheries given their mixed contribution to salmonid ESU recovery. For instance, hatcheries increase rates of straying; inappropriate hatchery management can lead to genetic mixing of discrete stocks; massive fish production can increase mortality of outmigrating smolts as can harvest of mixed stocks on their spawning run. On the other hand, conservation hatcheries may represent the last and best chance to retain seriously threatened ESUs; others can be used to rebuild natural runs; still others are required under treaty obligations.

We have advocated in previous reports that hatcheries be involved as experimental units in salmon restoration. Perhaps the primary goal of such research would be to expand the understanding of hatchery impacts on wild stocks, a global issue in ESU recovery and one pretty much independent of local conditions. An initial step should be to compile a file of information about state, tribal and federal hatcheries, the species being nurtured, and the status of wild salmon in the adjacent watersheds.

Because the decision to close hatcheries will not be made capriciously, NOAA Fisheries should be prepared to be opportunistic. A number of experimental designs seem possible, and we identify three here. First, if economic conditions dictate closure of some hatchery, every effort should be made to pair it with a comparable [control] hatchery. Response variables should be identified at this time and the appropriate monitoring strengthened or established. Replication is obviously necessary. A modification of the above scheme would be to establish threesomes: closed, functioning as usual, and one with production reduced by half. Such a design would quantify the density X survival effect, apparently strong in chinook and weaker in coho. Replication, if possible, would obviously make the derived inferences more robust. Again, response variables should be identified: the obvious one is density in hatchery x either out migrant or escapement survival. Coupling these results with cost/benefit models could lead to more effective hatchery policies. Last, habitat restoration, or at least reduction of loss, seems an attainable and desirable goal in many watersheds. Coupling control and closed hatcheries to changing watershed traits should contribute to disentangling the relative importance of these two Hs.

The closure of any hatchery, for whatever reason, should be seized on as an opportunity too rich in its potential to be disregarded. We urge NOAA Fisheries to examine the feasibility and power of such actions.

The panel emphasizes the necessity of an experimental approach to determine the positive and negative ecological and genetic influences of hatchery fish on the natural spawning population. This approach is also lauded by the ISAB. The goal of such experiments is not to decide whether hatcheries are unconditionally good or bad, but to clarify conditions under which hatcheries will aid recovery of the wild population versus impeding recovery or contributing to decline.

References:

Ruckelshaus, M., P. Levin, J. Johnson, and P. Kareiva. 2002. The Pacific Salmon Wars: what science brings to the challenge of Recovering Species. Annu. Rev. Ecol. Syst. 33:665-706.